Adaptive Channel Measurement Reporting

FIELD OF THE INVENTION

5   The present invention relates to a method and arrangements for achieving an improved and adaptive reporting of measurements for a communication channel between a transmitter and a receiver unit.

BACKGROUND OF THE INVENTION

10   Communication channels in telecommunication systems can often be measured with a sufficiently good accuracy in a receiver unit but often not in the transmitter unit. However, transmitter units in communication systems can benefit from knowing the properties of said channels through

15   adapting the transmitted signal, e.g., power, frequency, modulation scheme, or coding to said channel properties. It is therefore desirable to report results of channel measurements from a receiver unit, which can perform such measurements with the necessary accuracy, to the transmitter

20   unit, which needs indications of such measurements for adaptation of the transmitted signal.

In a prior art solution, which is used in present communications systems, e.g. GSM-systems or WCDMA-systems, mobile terminals can be instructed to periodically report

25   the downlink channel quality to the transmission unit in the network. This can be used for, e.g., Transmit Power Command (TPC-) messages, which are derived inter alia from the receiver's perception of the downlink channel, and transmitted back to the transmitter unit as an incremental

30   value to increase or decrease the downlink transmission power. This is described, e.g., in the technical specification TS25.214 (V.5.0.0) issued by the 3rd Generation

Partnership Project (3GPP). A low-detail knowledge of the channel, e.g. as a representation of the channel quality, can be useful to adapt the bit rate, and coding and modulation formats in the transmitter. However, such simple

5   channel quality reporting provides a too low level of detail for advanced adaptation of the transmitted signal, e.g. allocation of and power control for sub-carriers in an OFDM system, and is thus not useful for systems employing such techniques.

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SUMMARY OF THE INVENTION

It is desirable that the transmitter unit has a good knowledge of channel properties between transmitter and receiver unit. However, when providing such information from

15   the transmitter unit to the receiver unit it has been observed to be a problem that a representation of the channel function comprising a sufficiently large accuracy implies a considerably large amount of information that must be sent. This problem is not solved by corresponding

20   solutions according to the state of the art.

Therefore, it is the object of the present invention to achieve a method and arrangement providing a message format, which provides detailed channel information to a transmitter unit but requiring a minimised amount of transmission

25   capacity.

It is the principal idea of the present invention that the receiver unit delivers preferably incremental updatings of the filter function, represented in the time- or frequency-domain, of the entire channel between transmitter and

30   receiver. For this purpose the channel representing filter function is divided into a number of sub-functions, a function of which corresponding to the true channel filter

function, and whereof the various sub-functions contain channel information of a ranked degree of significance.

This idea is realised by the method and arrangement according to the present invention comprising a improved
5   message format for transmitting channel function information to the transmitter. Said message format includes information about at least a selection of the updated sub-functions of the channel function along with an indication of the channel information and function type.

10   It is an advantage of the present invention that the transmitter unit obtains with a comparatively low amount of signalling capacity a sufficiently detailed knowledge of the transmission channel between transmitter and receiver unit.

It is thus another advantage of the present invention that
15   the transmitter unit can in a fast manner adapt its transmission power to the necessary level.

Particularly in OFDM-based systems a detailed knowledge of the channel filter function, as provided by the present invention, allows, e.g., an efficient allocation of sub-
20   carriers to users and individual power control of said sub-carriers, e.g. through so-called water-filling (cf. Thomas M. Cover and Joy A. Thomas, *Elements of Information Theory*, John Wiley&Sons, 1991, Section 10.4.) along with an individual adaptation of modulation and channel coding per
25   sub-carrier. These advantages in turn enable a more efficient utilization of the channel, and thereby higher system capacity.

Other objects, advantages and novel features of the invention will become apparent from the following detailed
30   description of the invention when considered in conjunction with the accompanying drawings and claims.

For a better understanding, reference is made to the following drawings and preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a transmitter unit and a receiver unit communicating with each other via a multipath channel.

Figure 2a illustrates an example of a channel impulse response, e.g. for a transmission channel as shown in figure 1, while figure 2b shows a corresponding channel frequency response.

Figure 3 shows an example of a channel measurement message format according to the present invention.

DETAILED DESCRIPTION

Figure 1 shows a transmitter unit 11 and a receiver unit 12 communicating with each other via a multipath channel 14. In many radio channels the signal transmitted by the transmitter unit 11 reaches the receiver unit 12 via more than one path. For example, in a mobile communication environment, the transmitted signal is reflected off a variety of scatterers 13 such as buildings, trees, or moving vehicles. Thus, in addition to the direct path from the transmitter to the receiver, there are several other indirect paths, arising from the presence of the scatterers 13, that contribute to the composition of the received signal. The contributions from these indirect paths exhibit different signal attenuations and time delays relative to that from the direct path, i.e. they may interfere with the contribution from the direct path either constructively or destructively at the receiver input. The signal components

caused by the indirect paths are denoted multipath components and illustrated by a complex channel filter function either in the time domain as a channel impulse response, which is illustrated in figure 2a, or

5   correspondingly as a channel frequency response in the frequency domain as illustrated in figure 2b. The channel impulse response in figure 2a illustrates the contributions of the various multipaths in terms of complex parameters, which within the scope of the present invention are

10 reproduced, e.g., as an amplitude value A_i and a phase value φ_i or any other appropriate representation of complex values. The channel impulse response also denotes the delay times τ_i for said various multipaths. Correspondingly, the channel frequency response in figure 2b illustrates the frequency

15 selectivity of the multipath channel.

The method and arrangement according to the present invention intends to provide a channel measurement message format to efficiently inform the transmitter unit of measurements performed by the transmitter unit related to

20 the channel filter function between said units. For this purpose it is necessary to define the message properties representing the channel that must be transmitted in a message according to the inventive format.

A first aspect that must be considered for the inventive

25 message format relates to the representation of the channel filter function. Said function can be defined as a complex channel impulse response $h(\tau)$ in the time-domain or, alternatively, in the frequency domain as the channel frequency response $H(f) = F\{h(\tau)\}$, which is the Fourier-

30 transform of said channel impulse response. Both representations can imply specific advantages depending on, e.g., how fast or easy a certain information can be

retrieved from the one or other representation or depending
on how the transmitter unit is going to use the channel
information. The method according to the present invention
allows without preconditions to apply either of said
5   representations, e.g. on request of the transmitter unit.

A second aspect of the message format according to the
present invention is the manner in which the channel filter
function, in the time- or frequency domain, is represented
in said message. For instance, the channel impulse response
10   $h(\tau)$ as perceived by the receiver unit, is sub-divided into a
number N of sub-functions $h_n(\tau)$ for which the expression

$$f_{Rx}\big(h_0(\tau),\ldots\ldots,h_N(\tau)\big)=h(\tau)+\varepsilon_h$$

is at least approximately valid. $f_{Rx}(\cdot)$ denotes a modelling
function for achieving the appropriate channel impulse
15   response from a combination of said sub-functions while ε_h
($\varepsilon_h\ll h(\tau)$) indicates the deviation of the modelled channel
impulse response in the receiver unit compared to said
channel impulse response $h(\tau)$. From this modelled channel
impulse response the transmitter unit is able to re-create
20   an estimate

$$\hat{h}^{(n)}=f_{Tx}^{(n)}\big(h_0(\tau),\ldots\ldots,h_n(\tau)\big).$$

In an embodiment of the present invention said modelling
function $f_{Rx}(\cdot)$ can advantageously be realised as a summing
function such that the set of sub-functions at least
25   approximately fulfil the requirement

$$\sum_{n=0}^{N} h_n(\tau) = h(\tau) + \varepsilon_h .$$

The set of sub-functions $h_n(\tau)$ preferably comprises a kind of ranking with respect to their significance for the representation of the channel. $h_0(\tau)$ for instance may include

5   the most essential channel components, e.g. the largest channel component or the first component in time, i.e. the path with the shortest time delay. The accuracy of the estimate $\hat{h}^{(m)}$ in the transmitter unit depends on the number N of sub-functions as each sub-function provides additional

10 components of the channel impulse response but also on the number of sub-functions that are indicated to the transmitter unit.

As described for the time-domain, a corresponding sub-division into a number N of sub-functions applying an

15 appropriate modelling function $g_{Rx}(\cdot)$ can be performed for the channel frequency response $H(f)$ as perceived by the receiver unit, i.e.

$$g_{Rx}(H_0(f),......,H_N(f)) = H(f) + \varepsilon_H .$$

Further, the method according to the present invention is

20 improved over prior art solutions in the respect that it does not only allow a complete transmission of the channel filter function in one go or an incremental update of a single real value but instead does not restrict the possibility to transmit either representations of the actual

25 values of said function or representations of incremental values. Thus, a third aspect of the channel measurement message format relates to the characteristic of the transmitted information of the sub-functions, i.e. whether

it represents actual or incremental values. In a first
alternative, the message contains only the actual values in
terms of amplitude, phase, and time or frequency of the
channel filter function. Such a report, which is denoted a

5   basic report, can be advantageous as the first report
transmitted from the receiver unit to the transmitter unit
or in case of fast and/or significant changes of the channel
properties, e.g. caused by a moving obstacle within the
channel propagation area. It is another alternative to

10 transmit incremental reports, which denote changes of the
complex filter function values. This implies changes of the
complex values for the various channel filter sub-functions
compared to the previous report or, when applicable,
deviations of the actual channel filter function from a

15 modelled filter function, which can be obtained by a, e.g.
linear, interpolation of the already reported filter
function. In general, the estimate $h^{(k)}(\tau)$ of a reported new
measurement value of the channel filter function in the
transmitter unit can be regarded as the sum of the new

20 measurement value $h_k(\tau)$ and a weighted value representing
previously reported values, i.e.

$$h^{(k)}(\tau) = \alpha \cdot h^{(k-1)}(\tau) + h_k(\tau) \, .$$

A weighting value $\alpha = 0$ represents thus a basic report as it
does not include any previous information while a value $\alpha > 0$

25 represents an incremental report, which takes to a certain
degree, depending on the value for α, previous measurement
values into account. Yet another advantage when using said
weighting factor relates to the handling of faulty channel
measurement reports, in particular incremental reports,

30 where the influence of faults in previous measurements can
possibly be suppressed by help of a temporary decreased
weighting factor α for said measurements. For a basic report

on the other hand, it might turn out to be appropriate to
apply additional protection measures against transmission
faults.

Finally, a fourth aspect of the present invention relates to
5   the degree of accuracy with which the channel function
measurements are represented in a channel filter measurement
message. This can be controlled by means of selecting an
appropriate sampling of the channel filter function in the
time- or frequency domain. The easiest alternative is to
10   apply fixed sampling rates t_s or f_s for representing the
channel filter function in the respective domain. A fixed
sampling rate implies the advantage that the message format
representing the sub-functions of the channel filter
function does not need any additional indication of the
15   sampling rate. However, this approach is sufficient only in
case of a channel with little variations over time or
frequency. Preferably, the sampling is performed with
varying sampling rates, which allows, e.g. to apply a first
sampling rate for providing a basic report of a rough
20   representation of the channel sub-functions and then
providing a number of incremental reports which apply
successively finer sampling of the channel sub-functions.
Said incremental reports can contribute with actual values
or, in particular in the frequency domain, denote a
25   deviation from an interpolation of previously measurement
values whereas interpolations in the time-domain only fulfil
a purpose in case of dense sampling rates. In general it is
possible to apply appropriately selected sample times τ_s or
sample frequencies f_s, which, however, must be indicated in
30   the channel measurement message as explained below.

Figure 3 shows an example of the channel measurement message
format according to the present invention. Said message
format consists at least of a payload portion 32 including

for one or several of the sub-divided parts of the channel filter function the reproductions 322 of said parts, e.g. in terms of an amplitude value A_i and a phase value φ_i as described above. Optionally, said message format also
5   includes a header portion 31 providing information about the manner of representing the payload information. This header portion 31 is optional for those cases where the content format of said payload portion 32 is predetermined and thus already known to the receiver of messages according to this
10 message format. One example of the content of the header portion is an indication (α) 312 whether the payload portion 32 represents a basic report, i.e. actual channel filter function values, or a report, which is incremental to certain degree denoted by a value $\alpha > 0$. In a simple
15 embodiment it would already be sufficient to define α as a binary value, which only distinguishes between basic report and incremental report. Another example is a field (T/F) 311 indicating whether the channel measurement information refers to a representation of the channel filter function in
20 the time- or frequency domain. Finally it can turn out to be useful to provide an indication 313 of the sample base, i.e. whether the measurement is performed periodically in the time- or frequency domain. However, if the contributions of the sub-divided parts of the channel filter function shall
25 instead be reported for any time or frequency instance (τ_i or

f_i), these instances are indicated in a field 321 together with the reproductions 322 of the complex parameters.

Channel measurement messages can be transmitted at periodic instances of time or when it is considered to be necessary
30 either by the receiver unit or the transmitter unit. Events that trigger the receiver unit to send a measurement message of the channel filter function are, e.g., a detected fast change of the channel properties or, e.g., that the transmitter unit detects or is notified of a deviation

between the actual channel properties and the modelled or determined channel function in response to subsequent incremental reports from the receiver unit. The transmitter unit itself can influence the reporting of the channel filter function by the receiver unit by means of transmitting an appropriate transmitter message to the receiver unit. The message format for said transmitter message is similar to that of the channel measurement message. In a first embodiment said message only contains an indication of the type of channel measurement message that is requested next by the transmitter unit. The request can specify, e.g., whether the next channel measurement message denotes a representation of the channel filter function in the time- or frequency domain and/or the weighting factor α denoting to which degree the complex parameter values of said function are represented as actual values or incremental values. In addition to this, a second embodiment of said transmitter message also includes amplitude and phase values, and the according time or frequency instances if necessary, of a model of the channel filter function, which is applied in the transmitter unit. The receiver unit can then apply this channel model as a reference for incremental reports in the channel measurement message.

The present invention can advantageously be applied in a mobile radio communication system for improving, e.g., power management of the downlink channel from a radio base station to a mobile terminal. In general, the invention makes it possible for a transmitter to utilise detailed knowledge of the channel without using excessive amounts of communication resources on the opposite direction link, which will increase the system capacity as well as the user-experienced performance.